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Ergonomi – Bedömning av termisk påfrestning genom fysiologiska mätningar (ISO 9886:2004)

Ergonomics – Evaluation of thermal strain by physiological measurements (ISO 9886:2004)

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Ergonomics - Evaluation of thermal strain by physiological measurements (ISO 9886:2004)

Ergonomie - Evaluation de l'astreinte thermique par mesures physiologiques (ISO 9886:2004)

Ergonomie - Ermittlung der thermischen Beanspruchung durch physiologische Messungen (ISO 9886:2004)

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Foreword

This document (EN ISO 9886:2004) has been prepared by Technical Committee ISO/TC 159 "Ergonomics" in collaboration with Technical Committee CEN/TC 122 "Ergonomics", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2004, and conflicting national standards shall be withdrawn at the latest by August 2004.

This document supersedes EN ISO 9886:2001.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Endorsement notice

The text of ISO 9886:2004 has been approved by CEN as EN ISO 9886:2004 without any modifications.

Introduction

This document is part of a series of standards concerned with the assessment of thermal stress and strain.

This series of International Standards aims in particular at

a) establishing specifications for the methods of measuring physical parameters characterising thermal environments;

b) establishing methods for assessing thermal stress in cold, moderate and hot environments.

The analysis methods described by these latter standards allow the prediction of the average physiological response of subjects exposed to a thermal environment. Some of these methods are not applicable under exceptional climatic circumstances, when the characteristics of the exposed subjects differ greatly from the average or when special means of protection are used.

In these cases, or for the sake of research, it may be useful or even necessary to measure directly the physiological strain experienced by the subject.

This International Standard gives a series of specifications concerning the methods of measurement and interpretation of the physiological parameters considered as reflecting the response of the human organism placed in a hot or cold environment.

Ergonomics — Evaluation of thermal strain by physiological measurements

1 Scope

This International Standard describes methods for measuring and interpreting the following physiological parameters:

— body core temperature;

— skin temperatures;

— heart rate;

— body-mass loss.

The choice of variables to be measured and techniques to be used is at the discretion of those responsible for the health of the employees. These persons will have to take into account not only the nature of the thermal conditions, but also the degree of acceptance of these techniques by the employees concerned.

It should be emphasised that direct measurements on the individual can only be carried out on two conditions.

a) If the person has been fully informed about the discomfort and the potential risks associated with the measurement technique and gives free consent to such measurements.

b) If the measurements present no risk for the person which is unacceptable in view of general or specific codes of ethics.

In order to simplify this choice, Annex A presents a comparison of the different methods concerning their field of application, their technical complexity, the discomfort and the risks that they might involve.

This standard defines the conditions which are to be met in order to ensure the accuracy of the data gathered from the different methods. The measurement methods are described in Annex B. Limit values are proposed in Annex C (informative).

This standard is not concerned with experimental conditions for which investigators may develop alternative methods intended to improve knowledge in this area. It is however recommended, when conducting such studies in the laboratory, to use the methods described below as references, so that results may be compared.

Before using the evaluations methods described in this International Standard, the user is required to follow the ethics and legal rules in force in his country or institution. Accordingly, ethical committees will be consulted and rules concerning free written consent, freedom of participation, confidentiality, etc. will be strictly followed.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7933, *Ergonomics of the thermal environment — Analytical determination and interpretation of heat stress using calculation of the predicted heat strain*

3 Symbols and abbreviated terms

A_{Du} body surface area calculated from the Du Bois formula (m^2)

HR heart rate (beats·min^{-1})

HR_0 average heart rate (beats·min^{-1}) of the subject at rest while sitting under neutral conditions

HR_r heart rate (beats·min^{-1}) during a break in work after heart rate components due to static exertion and dynamic muscular work have disappeared

HR_L limit of heart rate (beats·min^{-1})

ΔHR_M increase in heart rate (beats·min^{-1}) linked with work metabolism

ΔHR_s increase in heart rate (beats·min^{-1}) linked with static exertion

ΔHR_T increase in heart rate (beats·min^{-1}) connected with the thermal strain experienced by the subject

ΔHR_N increase in heart rate (beats·min^{-1}) due to psychological factors

ΔHR_ε residual component in heart rate (beats·min^{-1}) connected with rhythm of breathing, circadian rhythm, etc.

I_{cl} thermal clothing insulation (clo)

k_i weighting coefficient for a point measurement

Δm body mass variation

M average metabolic rate (W/m^2)

Δm_{clo} mass variation due to variation of clothing or to sweat accumulation in the clothing

Δm_g gross body-mass loss

Δm_o mass loss due to the mass difference between carbon dioxide and oxygen

Δm_{res} mass loss due to evaporation in the respiratory tract

Δm_{sol} mass variation of the body due to intake (food) and excretions (stools) of solids

Δm_{sw} mass loss due to sweat loss during the time interval

Δm_{wat} mass variation of the body due to intake and excretion (urine) of water

p_a partial water vapour pressure in the air (kPa)

R respiratory quotient (dimensionless)

Δt time interval (min)

t_{ab} intra-abdominal temperature (°C)

t_{ac} auditory canal temperature (°C)

t_{cr} body core temperature (°C)

t_{es} oesophageal temperature (°C)

t_{or} oral temperature (°C)

t_{re} rectal temperature (°C)

t_{sk} skin temperature (°C)

t_{ski} local skin temperature at point i (°C)

t_{ty} tympanic temperature (°C)

t_{ur} urine temperature (°C)

4 Measurement of body core temperature (t_{cr})

4.1 General

The "core" refers to all the tissues located at a sufficient depth not to be affected by a temperature gradient through surface tissue. Temperature differences are, however, possible within the core depending on local metabolisms, on the concentration of vascular networks and on local variations in blood flow. The core temperature is thus not a unique concept and measurable as such. This temperature may be approximated by the measurement of temperature at different points of the body:

— oesophagus: oesophageal temperature (t_{es});

— rectum: rectal temperature (t_{re});

— gastro-intestinal tract: intra-abdominal temperature (t_{ab});

— mouth: oral temperature (t_{or});

— tympanum: tympanic temperature (t_{ty});

— auditory canal: auditory canal temperature (t_{ac});

— urine temperature (t_{ur}).

The order of presentation of these different techniques has been adopted only for the clarity of the presentation.

Depending on the technique used, the temperature measured can reflect

— the mean temperature of the body mass, or

— the temperature of the blood irrigating the brain and therefore influencing the thermoregulation centres in the hypothalamus. This temperature is usually considered for assessing the thermal strain sustained by a subject.

4.2 Measurement techniques for indicators of body core temperature

4.2.1 Oesophageal temperature (t_{es})

4.2.1.1 Principle of the method

The temperature transducer is introduced in the lower part of the oesophagus, which is in contact over a length of 50 mm to 70 mm with the front of the left auricle and with the rear surface of the descending aorta. In this position, the temperature transducer registers variations in arterial blood temperature with a very short reaction time.

The upper part of the oesophagus presses against the trachea and the measurement of temperature at that level is affected by breathing. On the contrary, if the transducer is placed too low, it records gastric temperature.

The temperature of the saliva swallowed by the subject also influences the transducer. The oesophageal temperature is therefore not given by the mean value of the recorded temperatures but by the peak values. This is particularly true in cold environments, where the saliva can be chilled.

4.2.1.2 Interpretation

Of all the indirect measurements of t_{cr} mentioned in 4.2.1.1, t_{es} is the one which most accurately reflects temperature variations in the blood leaving the heart, and in all probability, the temperature of the blood irrigating the thermoregulation centres in the hypothalamus.

4.2.2 Rectal temperature (t_{re})

4.2.2.1 Principle of the method

A temperature transducer is inserted in the rectum; this being surrounded by a large mass of abdominal tissues with low thermal conductivity, the rectal temperature is independent of ambient conditions.

4.2.2.2 Interpretation

When the subject is resting, the rectal temperature is the highest of the body temperatures. When the subject is working, on the contrary, t_{re} is directly affected by the production of heat from the local muscles: with an equal expenditure of energy per unit of time, t_{re} is higher when work is performed with the legs than when it is carried out exclusively with the arms.

t_{re} essentially gives an indication of the mean temperature of body core mass. It may only be considered as an indicator of blood temperature and therefore of the temperature of the thermoregulation centres when heat storage is slow and when work is performed using the whole body.

When heat storage is low and work is essentially performed with the legs, the measurement of t_{re} leads to a slight overestimation of the temperature of the thermoregulation centres.

On the contrary, in the case of rapid storage, during intense thermal stress of short duration, t_{re} rises at a slower rate than the temperature of the thermoregulation centres, continues to rise after the exposure has stopped and finally decreases progressively. Rising speed and lag time depend on the exposure and recovery conditions. In these cases, t_{re} is inappropriate for estimating the strain sustained by a subject.

4.2.3 Intra-abdominal temperature (t_{ab})

4.2.3.1 Principle of the method

The subject swallows a temperature transducer. During its transit through the intestinal tract, the temperature recorded will vary according to whether it is located in an area close to large arterial vessels or to organs with high local metabolism or, on the contrary, near the abdominal walls.

4.2.3.2 Interpretation

When the transducer is located in the stomach or the duodenum, temperature variations are similar to those of t_{es} and the difference between the two temperatures is very small. As the transducer progresses inside the intestine, the characteristics of the temperature come closer to those of t_{re}. Therefore, the interpretation will depend on the time elapsed since the swallowing of the transducer and on the speed of the gastro-intestinal transit for the given subject.

In the present state of knowledge, t_{ab} seems to be independent of ambient climatic conditions, except for strong radiant heat impinging on the abdomen.

4.2.4 Oral temperature (t_{or})

4.2.4.1 Principle of the method

The transducer is placed underneath the tongue, and is therefore in close contact with the deep arterial branches of the lingual artery. It will then provide a satisfactory measurement of the temperature of the blood influencing the thermoregulation centres.

The temperature measured nevertheless depends on the external conditions. When the mouth is open, thermal exchanges by convection and evaporation on the surface of the buccal mucus membrane contribute to a reduction in the temperature of the buccal cavity. Even when the mouth is closed, the temperature may be significantly lowered as a function of a reduction in the cutaneous temperature of the face, or raised if the face is exposed to strong radiant heat.

4.2.4.2 Interpretation

When the measurement conditions are met, t_{or} is very similar to t_{es}. With the subject resting and in environments in which air temperature is greater than 40 °C, t_{or} may overestimate t_{es} by 0,25 °C to 0,4 °C. With the subject working, the concordance between t_{or} and t_{es} is only established for muscular effort levels not exceeding 35 % of the maximal aerobic power of the subject.

4.2.5 Tympanic temperature (t_{ty})

4.2.5.1 Principle of the method

This method aims at measuring the temperature of the tympanic membrane whose vascularisation is provided in part by the internal carotid artery, which also supplies the hypothalamus. As the thermal inertia of the eardrum is very low, due to its low mass and high vascularity, its temperature reflects the variations in arterial blood temperature, which influence the centres of thermoregulation.

However, as the tympanic membrane is also vascularised by the external carotid artery, its temperature is influenced by the local thermal exchanges existing in the area vascularised by this artery. As the contact of a sensor with the tympanic membrane or the surrounding areas is painful, either a thermal transducer is placed as close as possible to the membrane or its temperature is measured using an infrared (IR) surface-temperature measurement device which is focussed on the membrane. However, in practice the infrared method often encounters significant problems (see B.1.6).